

Method for processing an ion current signal to determine start and quality of combustion

Patent number: GB2364128
Publication date: 2002-01-16
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Classification:
- **international:** F02D35/02
- **european:** F02D35/02; F02D41/14D3H2B
Application number: GB20010003920 20010216
Priority number(s): DE20001008553 20000224

Also published as:

US6614230 (B2)
US2002021120 (A1)
JP2001280194 (A)
DE10008553 (A1)

Abstract of GB2364128

The ion current signal is processed by offset correction 1 and the dielectric resistance determined from this offset is used to diagnose engine behaviour. The signal is integrated 4 for comparison with a threshold value A to identify combustion (path I). The quality of combustion (path II) is found by comparing an average value and/or the variance of the integrated signal 6 with a second threshold value. The signal is compared to a third threshold B to determine the start of combustion (path III) and the result checked for plausibility 10. The evaluations are limited to a specific crankshaft angle range and each ion current signal value can be averaged by a sliding mean value formation over a number of engine cycles.

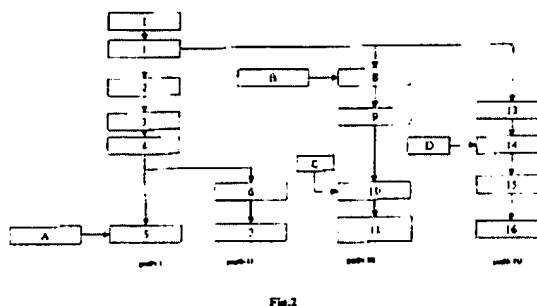


Fig. 2

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(12) UK Patent Application (19) GB (11) 2 364 128 (13) A

(43) Date of A Publication 16.01.2002

(21) Application No 0103920.5

(22) Date of Filing 16.02.2001

(30) Priority Data

(31) 10008553

(32) 24.02.2000

(33) DE

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(51) INT CL⁷

F02D 35/02

(52) UK CL (Edition T)

G1N NCGM N1A3B N1D11

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(58) Field of Search

UK CL (Edition S) G1N NAAJCR NACJ NADCC NADW

NAHHB NAHHC NCGM

INT CL⁷ F02D 35/02 41/14, F02P 17/12

ONLINE: WPI, EPODOC, PAJ

(54) Abstract Title

Method for processing an ion current signal to determine start and quality of combustion

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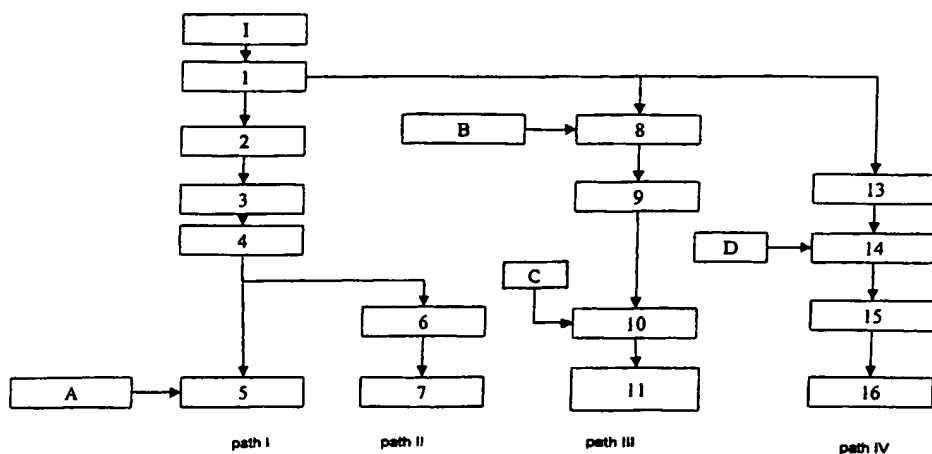


Fig.2

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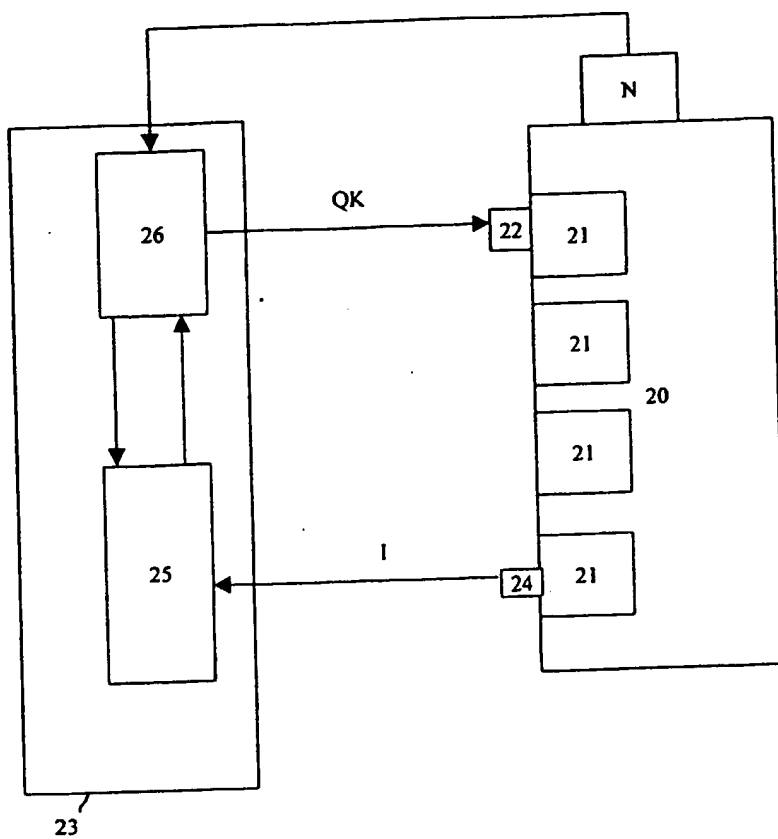


Fig.1

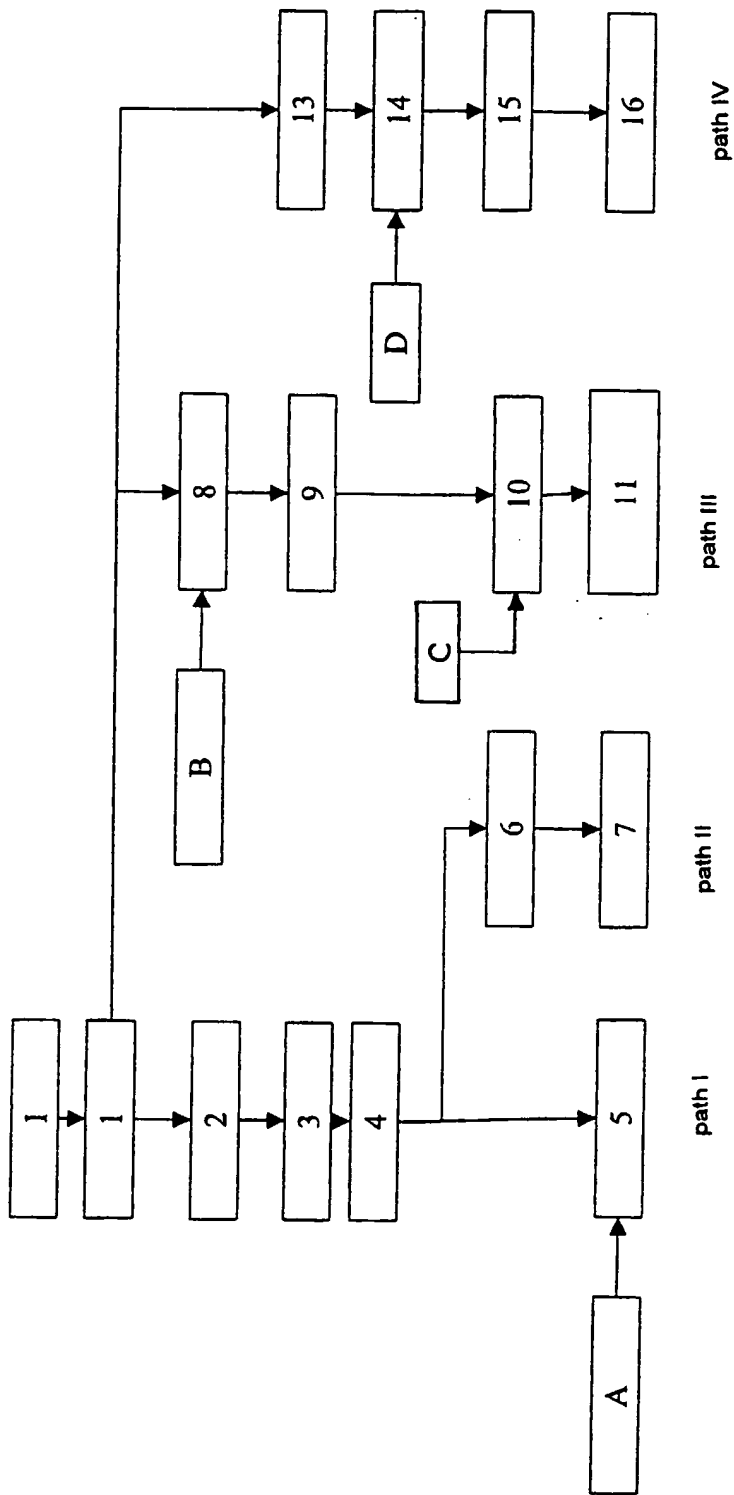


Fig.2

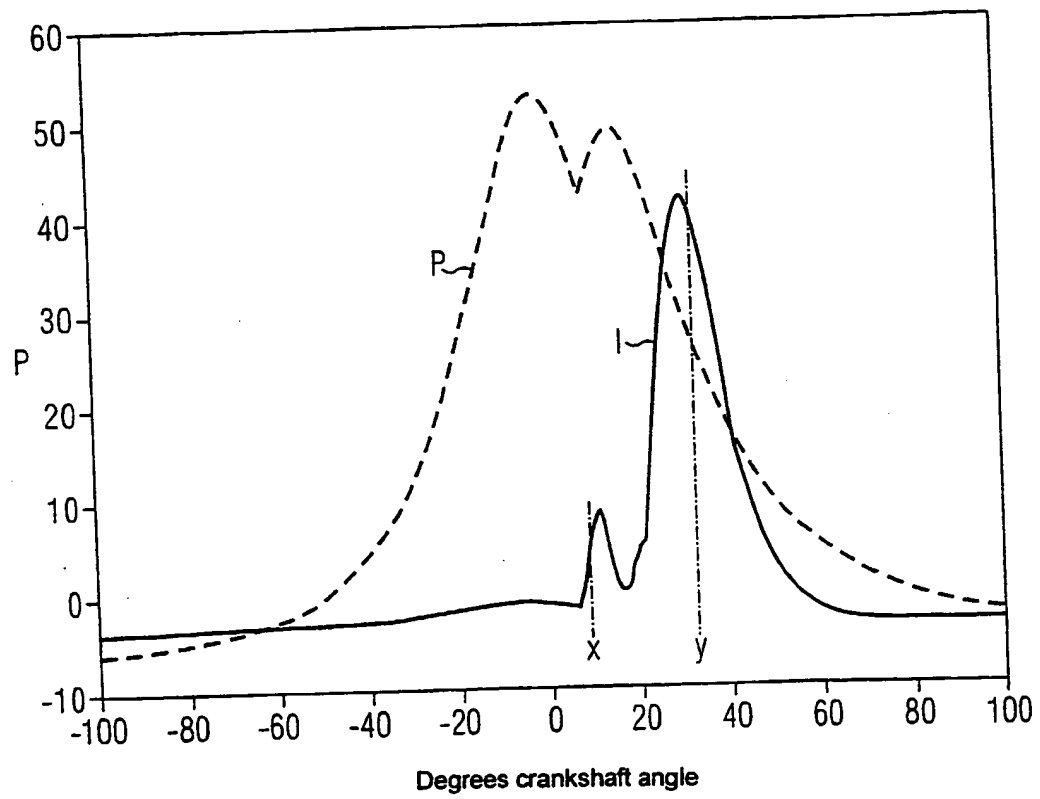


Fig.3

METHOD AND MEANS FOR PROCESSING AN ION CURRENT SENSOR SIGNAL

The present invention relates to a method and processing means for processing an ion current sensor output signal from an internal combustion engine.

A number of engine characterising magnitudes and states, such as combustion recognition, start of combustion, combustion point of concentration and combustion quality, can be determined on the basis of combustion chamber pressure. For that purpose, the combustion chamber pressure is detected by a special and separately mounted pressure sensor. This requires, for each cylinder, an additional bore in the cylinder head as well as a pressure sensor suitable for series production.

Ion current carbon sensors and other ion current sensors are also used for diesel engines. In that case, integration of the ion current sensor is possible not only in the glow plug, but also in the injector nozzle.

In EP 0 190 206 B1 there is disclosed a device for measurement and regulation of operating data of internal combustion engines, with an ion current sensor for specific detection of noxious components, such as soot, of an engine. In addition, further magnitudes required for regulation of the engine are detected by this ion current sensor.

There is therefore a need for a method and means for measurement and influencing of operating data of an internal combustion engine in order to optimise the combustion process.

According to a first aspect of the present invention there is provided a method of evaluating an ion current sensor signal of an internal combustion engine in that proceeding from a signal of the ion current sensor at least one magnitude which characterises the combustion in the internal combustion engine is determined, characterised in that at least one magnitude which characterises start of combustion and/or quality of combustion is detected by a preparation of the signal.

Preferably, the signal of the ion current sensor is subjected to an offset correction, starting from which the calculable dielectric resistance is used for diagnostic purposes. For preference, the signal is integrated and subsequently compared with a threshold value in order to recognise combustion. In addition, the quality of combustion can be determined starting from the integrated signal, wherein, in particular, a mean value and/or a variance of the integrated signal is or are compared with a second threshold value. Moreover, the start of combustion can be recognised starting from a comparison of the signal with a third threshold value.

Preferably, the ascertained magnitudes are checked with respect to plausibility by comparison with threshold values. These and the other threshold values can be preset in dependence on the actual operating point of the engine especially on load and rotational speed. Expediently, the evaluation takes place only within an angular range. For preference, the magnitudes are averaged over several working cycles, wherein, in particular, a sliding mean value formation can be carried out. The ascertained magnitudes can be used for, for example, control and/or regulation of a setting element of the engine.

According to a second aspect of the invention there is provided processing means for evaluating an ion current sensor signal of an internal combustion engine, with means which, starting from a signal of the ion current sensor, determine at least one magnitude characterising the combustion in the internal combustion engine, characterised in that means are provided which detect at least one magnitude, which characterises start of combustion and/or quality of combustion, by preparation of the signal.

Due to the strong fluctuations in the ion current sensor signal an appropriate signal processing is of importance for extraction of the parameters relative to combustion. In that case, the mode and manner of the communication or averaging has a decisive role in the extraction of the parameters.

It is an advantage that features of engine combustion can be made available for a control unit of the engine and an optimisation of the combustion in the desired sense can thereby be achieved. In that case, by contrast to the method with a combustion chamber pressure sensor, no additional bore is required.

An example of the method and an embodiment of the processing means according to the invention will now be more particularly described with reference to the accompanying drawings, in which:

- Fig. 1 is a schematic block diagram of an engine equipped with processing means embodying the invention;
- Fig. 2 is a flow chart showing steps for ascertaining operating data obtained by the processing means; and
- Fig. 3 is a diagram comparing an ion current sensor signal and a combustion chamber pressure sensor signal.

Fig. 1 shows an ion current processing and engine control system of a fuel-injected multi-cylinder internal combustion engine 20 with four cylinders 21. The rotational speed of the engine 20 is detected by way of the rotational speed sensor N, preferably an inductive pick-up, a Hall element, a magnetoresistive sensor or the like. The signal of the rotational speed sensor N is fed to an electronic control unit 23 for control of at least the injection of fuel for combustion in the engine cylinders. A respective element 22 by which a fuel quantity predetermined by the control unit 23 is admetered is associated with each cylinder 21. The elements 22 can be injectors of a common rail system, a pump-nozzle unit, distributor pump or other quantity setting element or elements. Preferably, quantity setting elements are used in which quantity admetering takes place over the actuation time of electromagnet valves or piezoelectric setters.

At least one cylinder is provided with an ion current sensor 24, the signal I of which is evaluated in an evaluating device 25 of the electronic control unit 23. A device 26 for quantity control of the fuel is part of the electronic control unit 23. The device 26 passes on different signals, for example different measurement magnitudes such as the rotational speed N, internal magnitudes, such as fuel quantity QK to be injected, and the injection start SB, to the evaluating device 25, where these magnitudes are processed together with the ion current sensor signal or signals. The result of this processing is fed to the device 26. The device 26 predetermines, starting from these signals, drive control signals for the quantity setting elements 22 of the cylinders 21.

An example of a method exemplifying the invention is illustrated in Fig. 2. Starting from the measured ion current signal I, an offset correction is undertaken in step 1. Compensation for fluctuations in the dielectric resistance is thereby possible.

Preferably, the dielectric resistance calculated from the offset current serves for diagnostic purposes. In particular, in the case of small injection quantities and thus a smaller ion current signal, a significant improvement of the signal can be achieved, starting from the offset correction in step 1, by a continuous compensation for disturbances synchronous with crankshaft.

The ion current is composed in simple terms of a first component, the offset current, which is given by the electrical resistance of the current circuit, and a second component, the actual useful information, which arises by virtue of the combustion and the resulting charge carrier and thus leads to a change in the resistance in the current circuit.

The first component, which can change with time, is calculated in a suitable crankshaft angular range and drawn upon for the evaluation (offset correction). The resistance (dielectric resistance) connected with the offset current is calculated according to Ohm's law. If this does not lie within a certain range, an error is recognised and suitable measures are initiated.

Interfering components may be added to these two components and compensation for these can be made by suitable measures, such as, for example, filtering.

Steps for recognition of combustion are illustrated in Fig. 2 as path I. A bandpass filtering is carried out in a step 2 and formation of amount in a subsequent step 3. Disturbances can thereby be eliminated. An integration of the signal I over an appropriate crankshaft angular range subsequently takes place in step 4. An energy magnitude results therefrom.

This energy magnitude is compared with a first threshold value, which is filed in a characteristic values field A, in a step 5. If the energy magnitude exceeds the threshold value A, then it is recognised that a combustion has taken place. The threshold value is read out of the field A in dependence on the actual operating state of the engine, which is preferably defined by the load and rotational speed.

Evaluation of recognised combustion from an appropriate number of succeeding work cycles is advantageous for secure recognition of combustion. For that purpose, preferably the values of a series of energy magnitudes from several successive combustions are averaged and subsequently compared with the threshold value. Alternatively, combustion can be finally recognised when the threshold value is exceeded several times.

The integration of the preliminarily prepared ion current signal takes place only in a previously established crankshaft angular range, preferably the angular range in which combustion is known to take place.

For recognition of combustion the thus-ascertained integrator value is compared with a threshold value which is filed in a characteristic values field, for example, in dependence on load and rotational speed. If the integrator value lies above the threshold, combustion has taken place. In the opposite case, no combustion has taken place. Thus, the signal of the ion current sensor is integrated and compared with a threshold value in order to recognise a combustion that has occurred. In that case the signal subjected to the offset correction is preferably used.

A magnitude which characterises quality of combustion can be detected by evaluation of the signal of the ion current sensor. In that case it is recognised, in particular, whether a combustion has taken place. The detailed ascertaining of the quality of combustion takes place starting from the output signal as ascertained in step 4. The integrated signal is subjected to a mean value formation in a step 6 of the path II. Moreover, the variance is ascertained in step 6. This is preferably carried out over several work cycles. The variance and/or the mean value is or are used for assessment of the quality of combustion. Assessment takes place in a step 7. In dependence on engine operating point (load, rotational speed), the quality of combustion is indicated by, for example, comparison with a reference characteristic values field (not shown).

Assessment of combustion quality is carried out by evaluation of the integral values of several combustions. For that purpose, substantially two characteristic values are calculated. The mean value indicates the mean of the integral values of the combustions under consideration. The variance indicates how strongly the integral values in question fluctuate. Statements about the quality of combustion are obtained by comparison of these two values with the values in a previously formed characteristic values field. For a

good quality of combustion, the mean value must exceed a certain value and the variance should not be too large. Thus, the signal of the ion current sensor is integrated and subjected to a mean value formation in order to ascertain a magnitude characterising the combustion quality. In that case the signal subjected to the offset correction is preferably used. As magnitudes characterising the combustion quality there are preferably used the mean value and the variance.

Determination of the start of combustion is illustrated in Fig. 2 on the basis of path III. Starting from the offset-corrected ion current signal a comparison with a threshold value takes place in a step 8 in an appropriate crankshaft angular range. The threshold value is filed in a characteristic values field B in dependence on the engine operating point (load, rotational speed). The angular setting at which the signal exceeds the threshold value is recognised in a step 9 as the start of combustion.

Determination of the start of combustion can also take place by parametric methods.

The result of the combustion start recognition is checked with respect to plausibility in a step 10. Involved in the checking are the combustion recognition, the combustion quality and the values of a characteristic values field C. Limits for a plausible combustion start are filed in the field C in dependence on engine operating point (load, rotational speed). In the case of presence of a plausible combustion start 10, this combustion start is taken into consideration in a step 11 by a subsequent averaging. The averaging in step 11 takes place over an appropriate number of work cycles. The averaging is preferably carried out as a sliding mean value formation. An averaging is necessary due to the fluctuations of the combustions and the ion current signals. This thus-ascertained combustion start can be used in the control of the engine as an actual value for the combustion start. In particular, this value can serve as an actual value of a combustion start regulation. Such a combustion start regulation can supplement or entirely replace the injection start regulation.

The combustion start is determined in a suitable crankshaft angular range, i.e. in the range in which the start of combustion can occur. The time instant or the crankshaft angle at which the ion current exceeds a previously established value is assumed as combustion start. Since the ion current is, in certain circumstances, subjected to strong fluctuations, the thus-ascertained values for the combustion start of the individual combustions are

averaged over an appropriate number of combustion cycles. Only the values for the combustion start of the individual cycles which lie in a plausible range are used for the averaging. The plausible range results thereby that in the case of an established injection time instant the start of combustion can lie only in a certain window after the injection time instant. Instead of recognition of the start of combustion by a threshold comparison, recognition can also be carried out with the aid of a parametric method. Parametric methods are mathematical methods of computation which utilise data concerning, for example, the form of the ion current signals, for a computation - which is better in this case - of the combustion start. This means that a model for the ion current is present and only a few parameters of the model still have to be determined.

Thus, the ion current sensor is compared with a threshold value in order to recognise the start of combustion. The signal subjected to the offset correction is preferably used in that case.

The ascertaining of the point of concentration of combustion is illustrated in Fig. 2 in path IV. After the offset correction of the ion current signal in the step 1, the calculation of the point of concentration in terms of area is carried out in a step 13 within a crankshaft angular range appropriate for the evaluation. The result is similarly subjected to a check with respect to plausibility in a step 14. This check is carried out on the basis of combustion quality, combustion recognition and a value of a characteristic values field D. Limits for a plausible point of concentration in terms of area are preset in the field D in dependence on engine operating point (load, rotational speed). In the case of a plausible result, the actual point of concentration in terms of area is taken into consideration in the subsequent averaging in a step 15. The averaging in step 15 is carried out over an appropriate number of combustion cycles and is preferably formed as a sliding mean value formation.

An averaging is necessary due to fluctuations of the combustions and the ion current signals. As the area point of concentration ascertained from the ion current can exhibit a constant displacement relative to the combustion point of concentration, which has been ascertained from pressure, in dependence on operating point, a correction with the aid of a characteristic values field (not shown) can be provided in step 16.

The combustion point of concentration is preferably used as an actual value for regulation of the combustion position. Moreover, it can be used as operating characteristic magnitudes for control and/or regulation of other setting magnitudes. Thus, for example, the injection start can be considered.

Instead of the point of concentration, other magnitudes, for example the centre of area, can be calculated. In that case the centre of area represents a specific crankshaft angle with the characteristic that, to the left and right of this position, there are identical areas of the ion current signal.

The calculation of the area point of concentration is carried out according to a conventional formula. This calculation delivers, as the result, the value for the angular position of the crankshaft or camshaft for the area point of concentration.

Since the ion current signal can vary very strongly, the result of the area point of concentration of each combustion must be checked with respect to plausibility. This is carried out on the basis of a characteristic values field in which limits for the beginning and end of the area point of concentration are indicated in dependence on the engine operational state. If the actually calculated area point of concentration lies outside the limits, this value is not used for the subsequent averaging. The averaging is carried out for generation of a stable area point of concentration, wherein the averaging length results as a compromise from the requirement of a rapid adaptation to changes of the operating point and from the desired stability of the area point of concentration. A downstream correction, which is dependent on engine operating point, is carried out with a characteristic values field for generation of a value which corresponds to the combustion point of concentration of the pressure and thus can be used for a regulation.

If so desired, for recognition of the start of combustion and of the combustion point of concentration an averaging is carried out in the path III and path IV directly after the offset correction. The averaging is carried out in that case by way of the prepared time signals of the ion current. In that case only the combustions which contain sufficient information are used for the averaging.

The recognition of the start of combustion and the combustion point of concentration are illustrated by way of example in Fig. 3 on the basis of the method exemplifying and

processing means embodying the invention. The point of concentration of combustion is generated from the area point of concentration of the ion current by correction with a characteristic values field in the step 16 dependent on operating point.

Fig. 3 shows, by the dashed line P, the pressure course in the cylinder and, by the solid line I, the ion current sensor signal recorded against crankshaft angle (degrees crank angle). Moreover, the start x of burning and the area point of concentration y are marked by vertical dot-dashed lines.

The pressure course has, before top dead centre at 0 degrees, a maximum value, dips around the top dead centre and then rises to a second, smaller maximum value. The ion current sensor signal has, at about the region of dipping of the pressure course, a first small peak and, at about 30° crankshaft rotation after top dead centre, a maximum value.

It is particularly advantageous in that case that the ascertained magnitudes, for example the start of combustion, the magnitudes which characterise combustion having taken place and/or the quality of combustion, are checked with respect to plausibility by comparison with threshold values.

The threshold values with which the ion current signal values are compared in order to ascertain the magnitudes and/or recognise plausibility are preferably presettable in dependence on the actual engine operating point, especially load and rotational speed.

In order to simplify signal preparation, the evaluation preferably takes place only within an angular range. This angular range of the crankshaft or the camshaft corresponds to the angular range in which the combustion predictably takes place.

A more reliable ascertaining of the magnitudes results through an averaging over several work cycles, i.e. several combustion cycles. Preferably, a sliding mean value formation is carried out.

CLAIMS

1. A method of processing an output signal of an ion current sensor detecting ion current in a combustion chamber of an internal combustion engine, comprising the step of processing the signal to obtain at least one magnitude characterising start and/or quality of combustion.
2. A method as claimed in claim 1, comprising the step of carrying out offset correction of the ion current signal.
3. A method as claimed in claim 2, comprising the step of determining dielectric resistance in dependence on the offset correction and diagnosing engine behaviour on the basis of the determined resistance.
4. A method as claimed in any one of the preceding claims, wherein the step of processing the ion current signal comprises integrating the signal value and comparing the integrated value with a threshold value for recognition of combustion.
5. A method as claimed in any one of claims 1 to 4, wherein the step of processing the ion current signal comprises integrating the signal value and comparing at least one of a mean value and a variance of the integrated signal with a threshold value for recognition of the quality of combustion.
6. A method as claimed in any one of the preceding claims, wherein the step of processing the ion current signal comprises comparing the signal value with a threshold value for recognition of the start of combustion.
7. A method as claimed in any one of the preceding claims, wherein the obtained magnitude is compared with a threshold value to determine the plausibility of the magnitude.
8. A method as claimed in any one of claims 4 to 7, comprising the step of setting the or each threshold value in dependence on engine operating state.

9. A method as claimed in claim 8, wherein the state is defined by engine speed and engine load.
10. A method as claimed in any one of the preceding claims, wherein the step of processing is carried out only within a predetermined angular range of crankshaft rotation.
11. A method as claimed in any one of the preceding claims, wherein the step of processing the signal is carried out to obtain a series of such magnitudes for a succession of combustion cycles and the magnitudes are averaged over a plurality of the cycles.
12. A method as claimed in claim 11, wherein the averaging comprises sliding mean value formation.
13. A method as claimed in any one of the preceding claims, comprising the step of utilising the obtained magnitude or magnitudes for at least one of control and regulation of a setting element influencing operation of the engine.
14. A method as claimed in claim 1 and substantially as hereinbefore described with reference to the accompanying drawings.
15. Processing means for processing an output signal of an ion current sensor detecting ion current in a combustion chamber of an internal combustion engine, the processing means comprising means for processing the signal to obtain at least one magnitude characterising start and/or quality of combustion.
16. Processing means substantially as hereinbefore described with reference to the accompanying drawings.



Application No: GB 0103920.5
Claims searched: 1-16

Examiner: Pierre Oliviere
Date of search: 19 October 2001

12

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK CI (Ed.S): G1N NAAJCR, NACJ, NADCC, NAHHB, NAHHC, NADW
Int CI (Ed.7): F02P 17/12, F02D 35/02, 41/14
Other: Online: EPODOC, WPI, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	US 6006727 (MITSUBISHI) Columns 3 and 10	1, 4, 10-13 and 15
X	US 5778855 (FORD) Columns 1, 3 and 5	1, 4 and 13
X	US 5452603 (DAIHATSU) Columns 1 and 2	1, 4-6, 10, 13 and 15
X	US 5396176 (HITACHI) Columns 2 and 3	1, 4 and 13
X	FR 2765275 A1 (ROBERT BOSCH) Pages 3 and 4	1, 2, 4, 8, 9 and 15
X	DE 19755247 A (DAIMLER) Abstract	1, 4 and 10

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